Bull. Southern California Acad. Sci.
84(3), 1985, pp. 113–126

Feeding Relationship of Two Species of Epizoic Amphipods and the Gray Whale, *Eschrichtius robustus*

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A mutualistic relationship exists with the gray whale, *Eschrichtius robustus,* and two species of Whale-Lice (Amphipoda: Cyamidae) because of the feeding regime of the cyamids. *Cyamus scammoni* Dall, 1872 and *Cyamus ceti* (Linnaeus 1758) apparently feed on the irritated epidermis of the gray whale surrounding the embedded, species-specific, ectocommensal barnacle *Cryptolepas rhachianecti* Dall, 1872 (Balanomorpha: Coronulidae). Feeding by the cyamids on the supporting skin may undermine the barnacle and ultimately cause it to become detached. The feeding area under and adjacent to the barnacle undergoes a color change from the original gray-black to white resulting in the white, circular scars characteristic to the gray whale. A third species of Cyamid, *Cyamus kessleri* Brandt, 1872 also occurs on the gray whale, but its role has yet to be determined.

The ecological relationship between whales and their external associates has been a source of conjecture at least from the time whale lice were first described by Linnaeus (1758), Brandt (1872), and Dall (1872). The gray whale, *Eschrichtius robustus,* with its three species of whale lice (*Cyamus scammoni, C. ceti* and *C. kessleri*), and one species of barnacle (*Cryptolepas rhachianecti*) is no exception. Leung (1976), in reference to the gray whale and its cyamid assemblage, speculated that "whale-lice are omnivorous, feeding on algal filaments and the outermost layer of skin tissue of the host" and possibly feeding as well on "the cutaneous tissue of the host, as the young customarily encases itself by piercing the delicate skin tissue or embedding itself in the cleavages of the sessile cirriped when it begins to maintain its livelihood." Noble and Noble (1976) characterized the whale-lice as "semiparasites" that burrowed into the skin of their host.

Methods

Data were obtained from seven beached gray whales (Table 1) and from observation of live, free-ranging gray whales. Live cyamid and barnacle assemblages were maintained, observed, and photographed *in situ* on stranded animals (Table 1). Live specimens of cyamid and barnacle associations, together with relatively fresh and undamaged sections of whale skin, were collected for further study (Figs. 1 and 5). All seven whales in Table 1 were collected from Southern California beaches during a six year period (1974–1979). None of the beached whales had been dead for more than two days. Observations and photographs were also made from various sized vessels and at close quarters (Fig. 3) ranging in the North from

Table 1. Strandings of Gray Whale in Southern California, 1974–1979.

Date collected/ observed	Sex	Estimated maturity[1]	Field number[2]	Total length	Stranding location
13 May 1974	Female	1 year	LACM-54544	6.9 m	San Clemente
20 Apr 1975	Female	20+ years	LACM-54545	13.0 m	Camp Pendelton
24 Feb 1976	Female	1 year	LACM-54548	7.9 m	Newport Beach
May 1976	Male	1 year	LACM-54549	7.7 m	Terminal Island
22 Nov 1976	Male	1 year	LACM-54550	6.5 m	Point Vincente
23 Jan 1977	Female	1–2 years	*WFS-1035	8.4 m	Los Angeles Harbor
20 Jan 1979	Male	1 year	*WFS-1042	7.2 m	Bolsa Chica State Beach

[1] After V. V. Zimushko 1970.
[2] Specimens and materials collected deposited in the Natural History Museum of Los Angeles County (LACM).
* No LACM numbers assigned; W.F.S. = W. F. Samaras Field Book Number (#4).

Point Conception, California, U.S.A. to Bahia Magdalena, Baja California Sur, Mexico in the south (including Scammon's Lagoon and Laguna Guerrero Negro in Baja California) from 1972 through 1981. Special attention was given to the distribution and density of cyamids and barnacles and to the types and shapes of scars and color patterns on the skin of gray whales.

Discussion

Cyamus scammoni (Fig. 2a) is the most easily identified of the three species (Fig. 2) of whale-louse found on the gray whale. It is the largest, most robust (20 mm in length), and darkest of the three. Live specimens are rather dull brownish-purple and are distinguished by two pairs of paired, corkscrew-like gills projecting ventrally from peraeon segments 3 and 4 (Margolis 1955; Hurley and Mohr 1957; Leung 1967).

A mature *C. ceti* (approximately 12 mm in length) is smaller than a mature *C. scammoni. C. ceti* is distinguished by its muted ochre color and two pairs of club-like gills. Each pair, emerging from peraeon segments 3 and 4, are carried laterally and curve anteriorly towards the cephalon (Fig. 2b). Segments 3 and 4 also carry one pair of short accessory gills projecting ventrally from the insertion of the primary gills. *C. kessleri* (c. 15 mm in length) resembles *C. ceti* but its peraeon is more laterally compressed and orange to coral in color. The long, baton-like gills, each pair emerging from peraeon segments 3 and 4, are also held latero-anteriorly but extend parallel to and beyond the cephalon (Fig. 2c). It has, like *C. ceti,* paired, bifurcated accessory gills on segments 3 and 4 which are attached ventrally at the insertion of the primary gills. These are short organs of subequal length.

There appears to be a species-oriented pattern of distribution of the cyamids on the gray whale as described by Rice and Wolman (1971) and Leung (1976). *C. scammoni* predominates in areas of heavy concentrations of barnacles on the head and trunk, particularly in wounds where necrotic tissue is present. *C. ceti* usually occurs anterior to the axilla of the pectoral fin and displays a distinct preference for skin folds, especially about the eyes, blowholes, throat grooves, and the gape of the mouth. *C. ceti* is a minor feeding competitor of *C. scammoni*

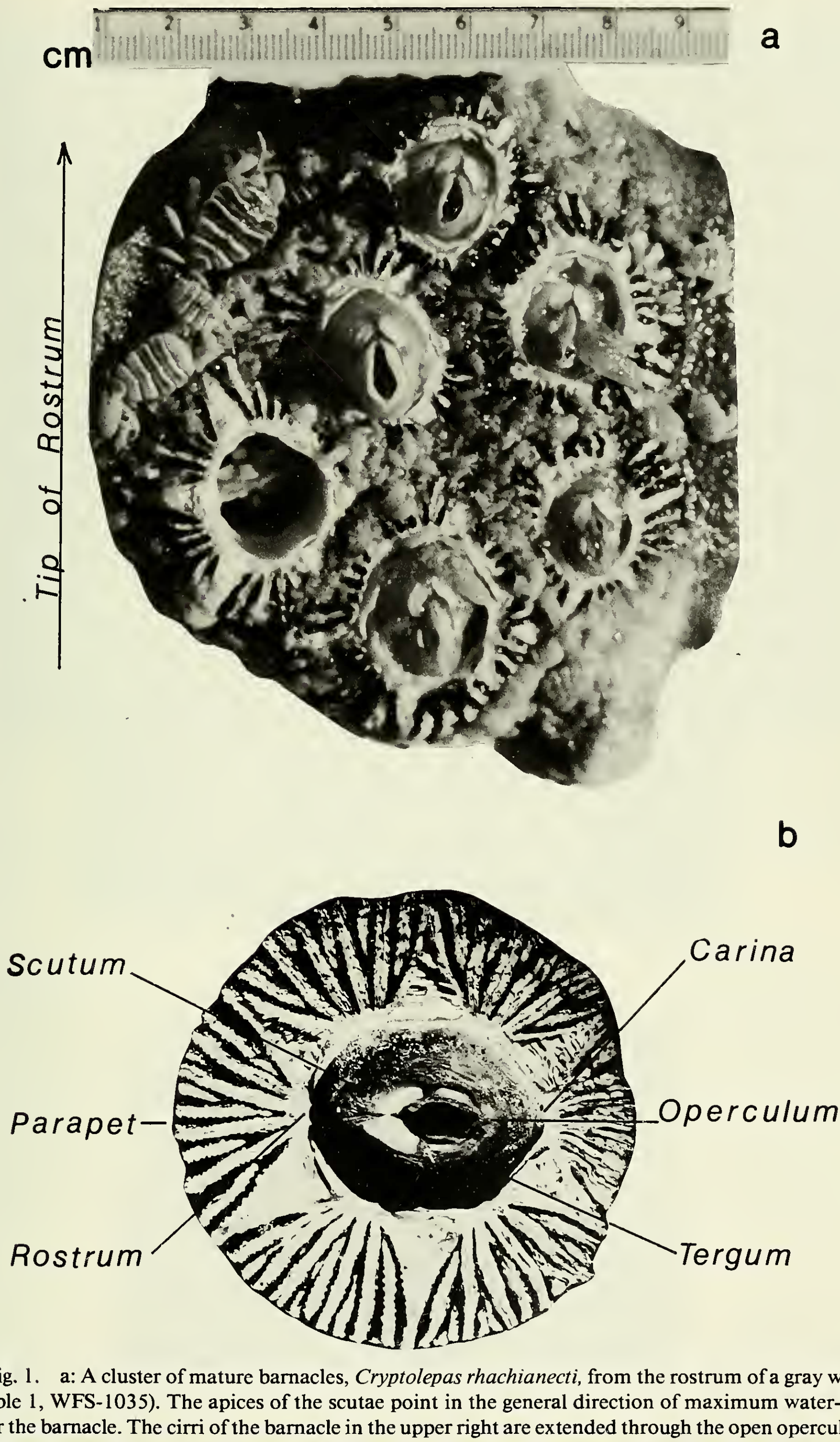
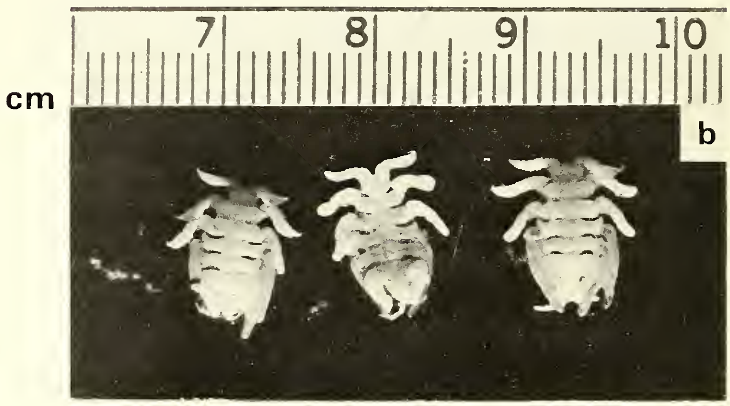
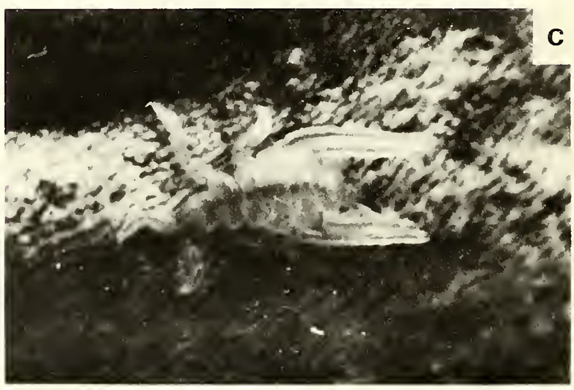


Fig. 1. a: A cluster of mature barnacles, *Cryptolepas rhachianecti,* from the rostrum of a gray whale (Table 1, WFS-1035). The apices of the scutae point in the general direction of maximum water-flow over the barnacle. The cirri of the barnacle in the upper right are extended through the open operculum. The identifiable cyamids are *Cyamus scammoni.* b: *Cryptolepas rhachianecti,* showing major anatomical features.

Cyamus scammoni



Cyamus ceti



Cyamus kessleri

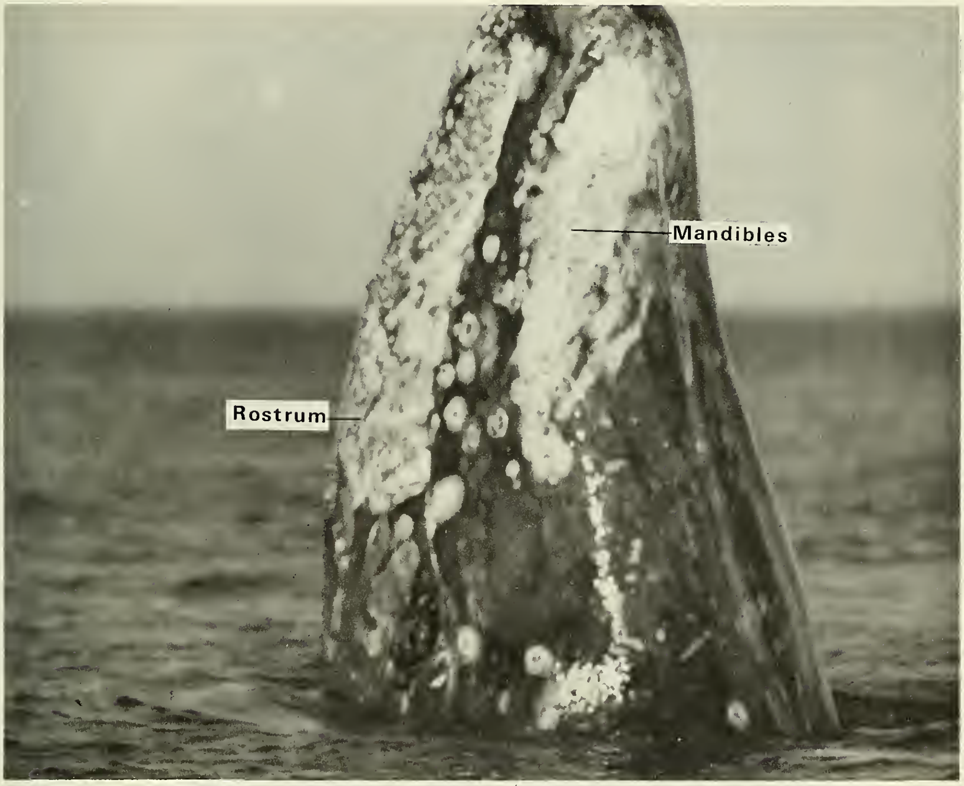


Fig. 3. Head of a spyhopping gray whale, showing areas of cyamid and barnacle concentration. In the area of the rostrum, the barnacles with their concomitant array of cyamids are packed together, forming an almost continuous mantle from the blowholes to the tip of the rostrum. On the mandibles, the barnacles are unevenly scattered either as isolated individuals or as small clusters. Photograph by Stephen Leatherwood (Scammon's Lagoon, Baja California Sur, Mexico).

around barnacles larger than 20 mm. *C. kessleri* is found consistently in trunk folds and orifices posterior to the pectoral fins, particularly in the mammary and urogenital openings. It has not been found in association with barnacle clusters.

The barnacle *Cryptolepus rhachianecti* is species-specific to the gray whale. Its orientation and alignment on the host may be directly related to efficient food acquisition (Rice and Wolman 1971). The rostrocarinal axes of the barnacle on the surface of the gray whales (Fig. 1) are characteristically aligned with the longitudinal axis of the whale (Rice and Wolman 1971). This alignment is consistent with the pattern of maximum laminar waterflow over specific parts of the

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Fig. 2. The three species of whale-lice (Arthropoda: Cyamidae) that infest the epidermis of the gray whale. a: *Cyamus scammoni*, the largest and numerically most abundant of the gray whale cyamids (Durham, unpublished). b: *C. ceti* is more commonly found anterior of the blowholes and in and around skin folds. c: *C. kessleri*, the least abundant of the three species of cyamids, is found primarily in the region of the urogenital aperture and anus (Samaras and Durham, pers. obs.).

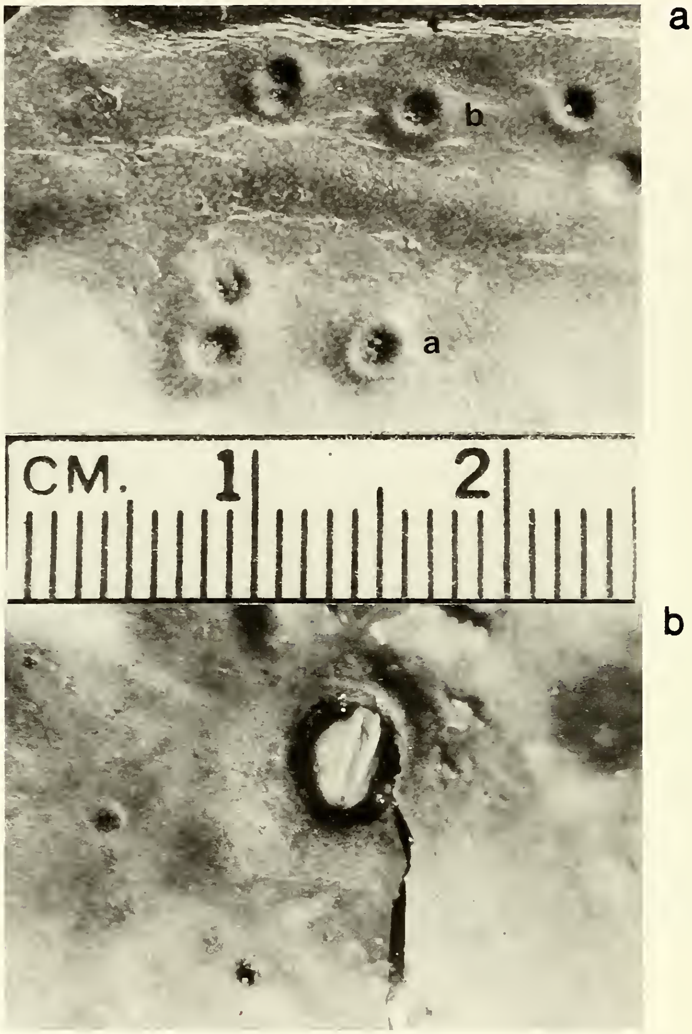

Fig. 4. Possible penetration and/or insertion pits. a: Miniscule, crater-like, attenuated pits in the epidermis of a yearling gray whale (Table 1, LACM-54548), apparently caused by the penetration or insertion mechanism of the cirriped cypris larvae. b: "Seed barnacle" that has not yet developed its protective, calcareous parapet. Notice that the surrounding crater and rim in the whales's epidermis are identical to those in *a* above. Magnification 4×; *a* and *b* to the same scale.

body, i.e., the rostrum and pectoral fins (Figs. 1a and 8) as described by Briggs and Morejohn (1972). With this orientation, the apices of the scutae, as well as the extended cirri of the barnacle, point in the direction of the whale's movement. Tightly packed clusters of barnacles in all stages of maturation, along with encrusting cyamids, may occur from the tip of the rostrum to the blowholes, forming an almost continuous mantle. A few small clusters are unevenly distributed over the throat region and jaws (Fig. 3). Barnacles are sporadically distributed from the blowholes posteriorly to the tips of the flukes. Large, mature barnacles may occur singly and occasionally with one or two small adjacent ones. Barnacles on

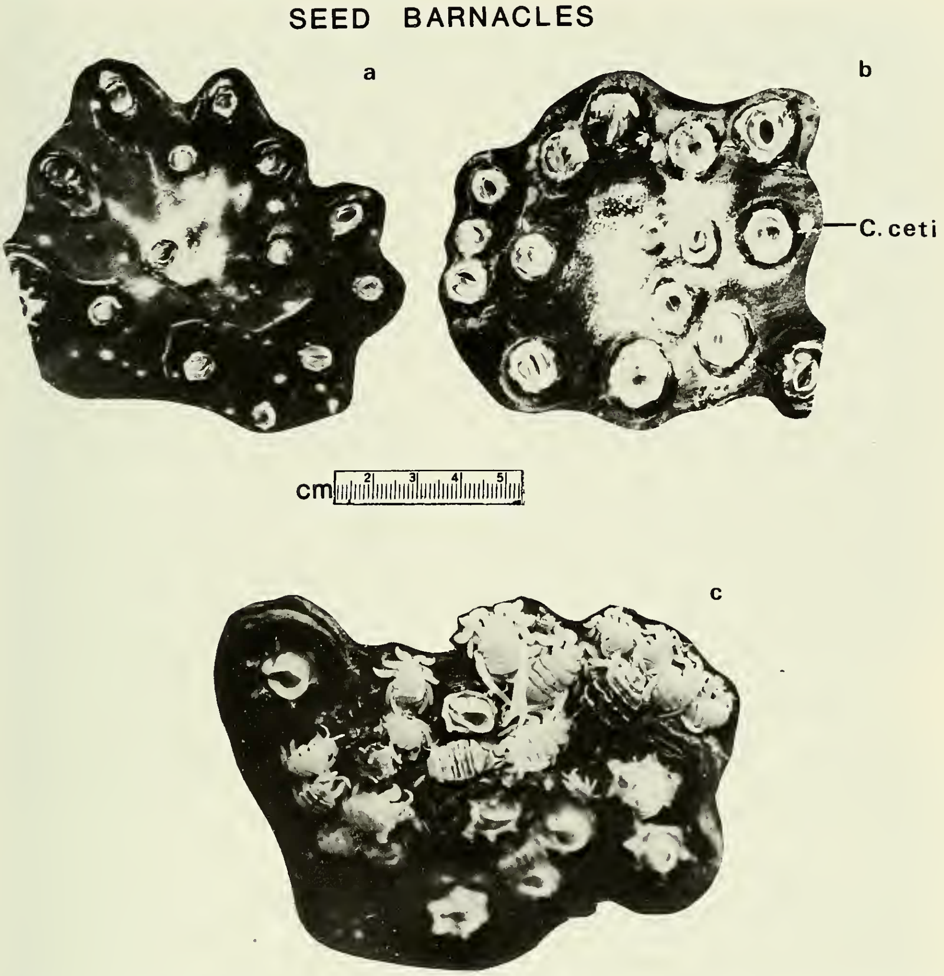

Fig. 5. a: Cluster of small seed-barnacles up to 5 mm in diameter. The white pigment transformation of dermis suggests that feeding by cyamids has commenced. b: Barnacles, 10–15 mm in diameter with calcareous parapets. The only large cyamid among these barnacles is *Cyamus ceti*. c: Feeding assemblage composed of at least eleven *C. ceti* and five *C. scammoni*. *a, b,* and *c* are the same scale. Photograph *c* by Terri Hoban (LACM-54544).

various parts of the gray whale may range in size from "seed" barnacles, 3–10 mm in diameter (Figs. 5a, b, 8, and 9), to mature ones, 40–60 mm in diameter (Fig. 6a).

The external anatomy of a mature barnacle is shown in Figure 1b. There are two major regions: one composed of six over-lapping plates forming the shell or parapet; and a second containing the opercular valves consisting of two scutae and two terga (Fig. 1b). The expanded and fluted basal portion of each of the six plates form the basis, and the primary attachment region of most cirripeds. In its dorsal aspect, the barnacle resembles a six-pointed star with a circle in its center. It is elliptical in cross-section.

As in most cirripeds, the free-swimming cypris larva is the stage during which

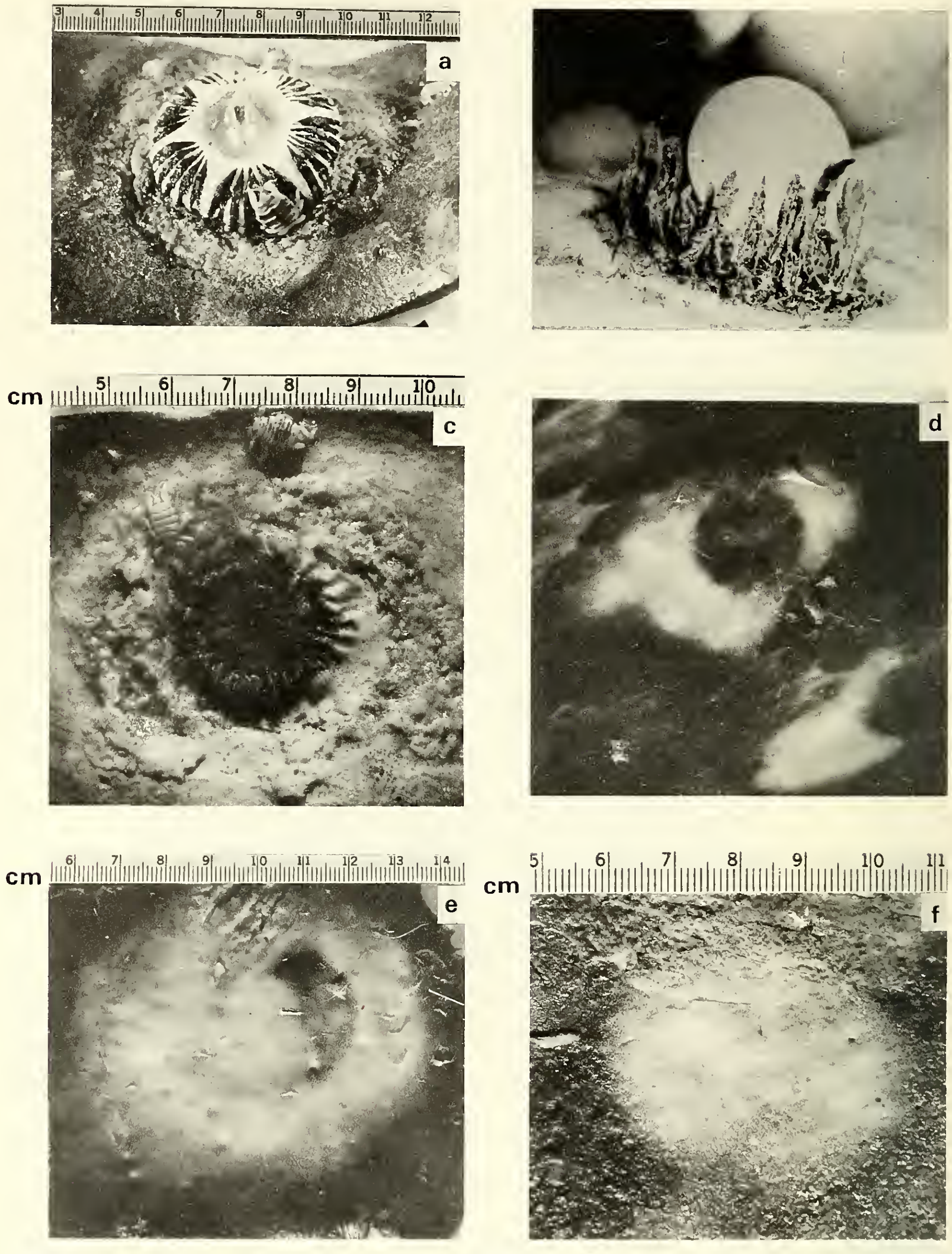

Fig. 6. Stages of scarification from terminal undercutting of *Cryptolepas rhachianecti* to complete dermal pigment transformation. a: A nearly completely undercut barnacle. The furrow excavated by feeding *Cyamus scammoni* is evident around its periphery. Basal excavation is also apparent. b: Site of a very recently removed barnacle. The fasicles of corium papillae that had grown between the barnacle's radial parapet flutes are apparent here as vertical structures. The object in the background is a penny. c: Characteristic scar created by peripheral basis-attachment processes. Cyamid induced excavation of the skin and subsequent pigment transformation are evident in this plate. The cyamids are *C. scammoni.* d: Wound left by the ablated barnacle. Cyamid-induced abrasion has almost completely healed with the replacement of the coreum, but pigment transformation from gray-black to white continues. e: Pigment transformation is almost complete. f: Complete pigment transformation has produced the characteristic round to oval barnacle scar seen on gray whales.

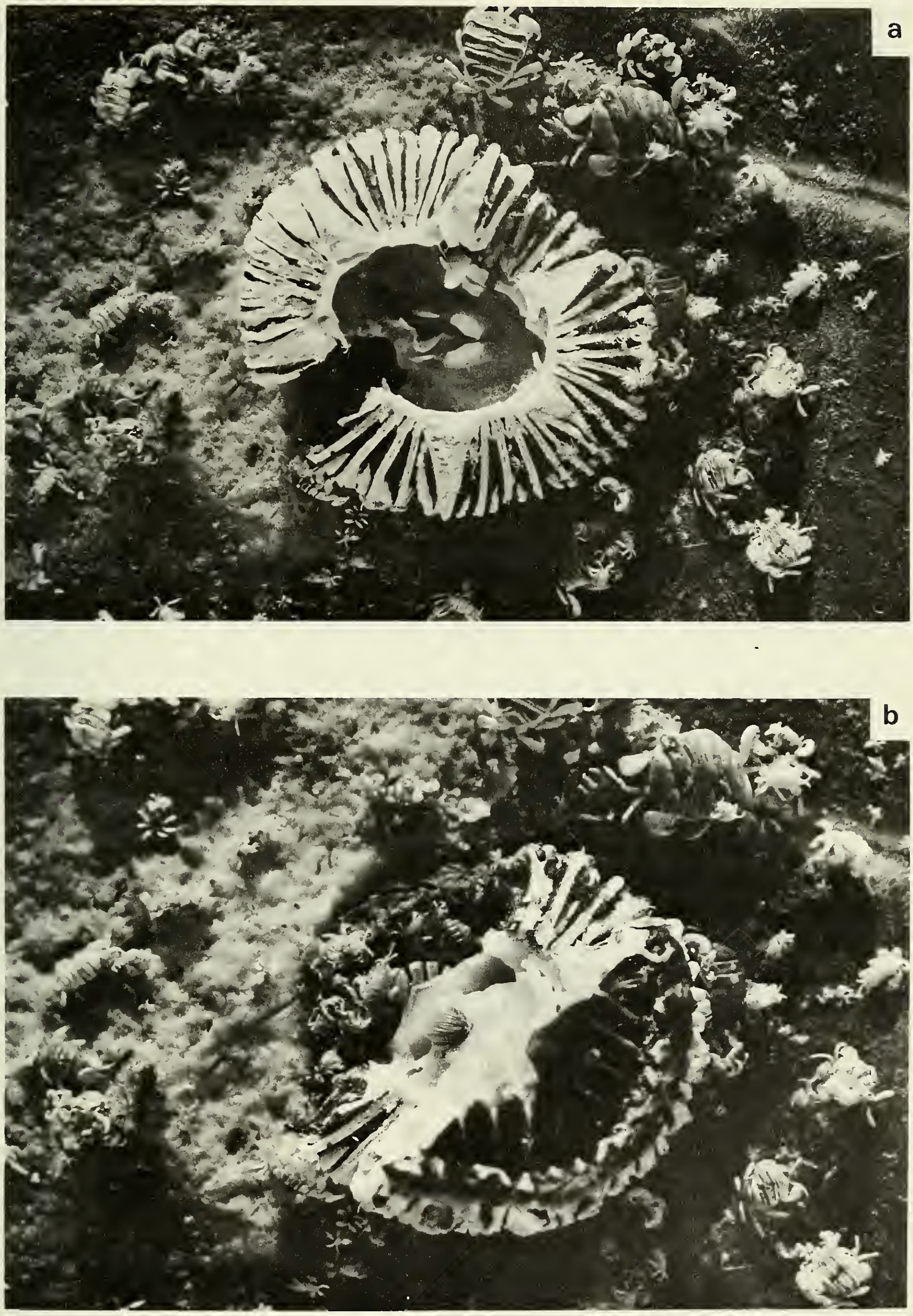

Fig. 7. Near terminally undercut, fully matured, *Cryptolepas rhachianecti*. a: Parapet was broken by authors. Notice cyamid-induced abrasions around periphery of barnacles. b: Parapet pulled back, revealing cyamids that had burrowed beneath the barnacle. This process ultimately relieves the supporting skin and the barnacle drops off the whale.

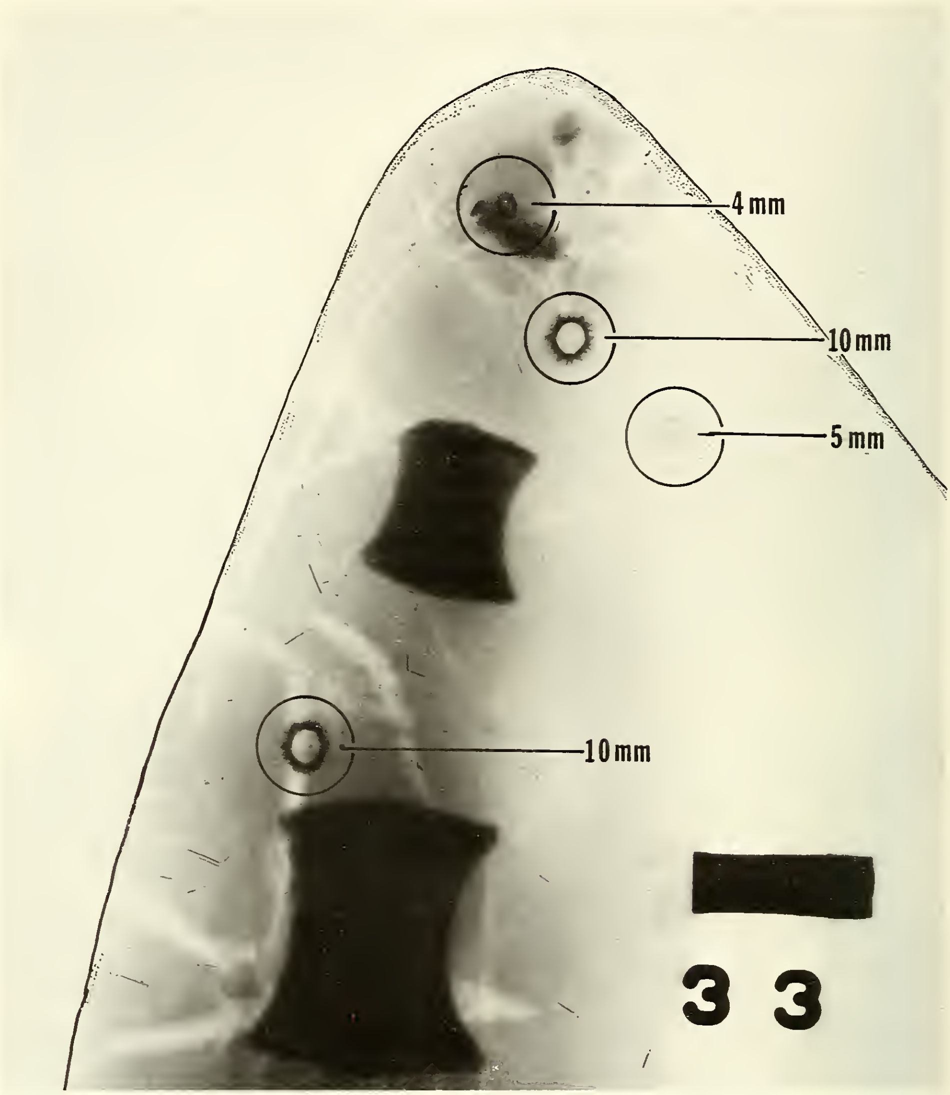

Fig. 8. X-ray of four seed barnacles on the distal tip of the right pectoral fin of a yearling, male gray whale (Table 1, LACM-54549).

attachment occurs. Initial attachment of the cypris larva of *Cryptolepas rhachianecti* has not yet been observed. Evidence based on the development and growth pattern of *C. rhachianecti,* along with the analysis of specimens by means of cross-sections and x-rays (Figs. 5a, b, and 9) of "seed" barnacle-rich gray whale skin, show that juvenile barnacles (3–10 mm in diameter) grow subcutaneously outward towards the epidermis. The juvenile barnacle (3–4 mm in diameter) appears to grow first vertically through the corium and corneum (Fig. 9b), then laterally through the epidermis (Figs. 1a, 5a, b and 7a). The presence of puncture-like pits or wounds in the immediate proximity of newly erupted "seed" barnacles (Fig. 4b) suggests possible similarities of initial attachment to that of parasitic cirripeds

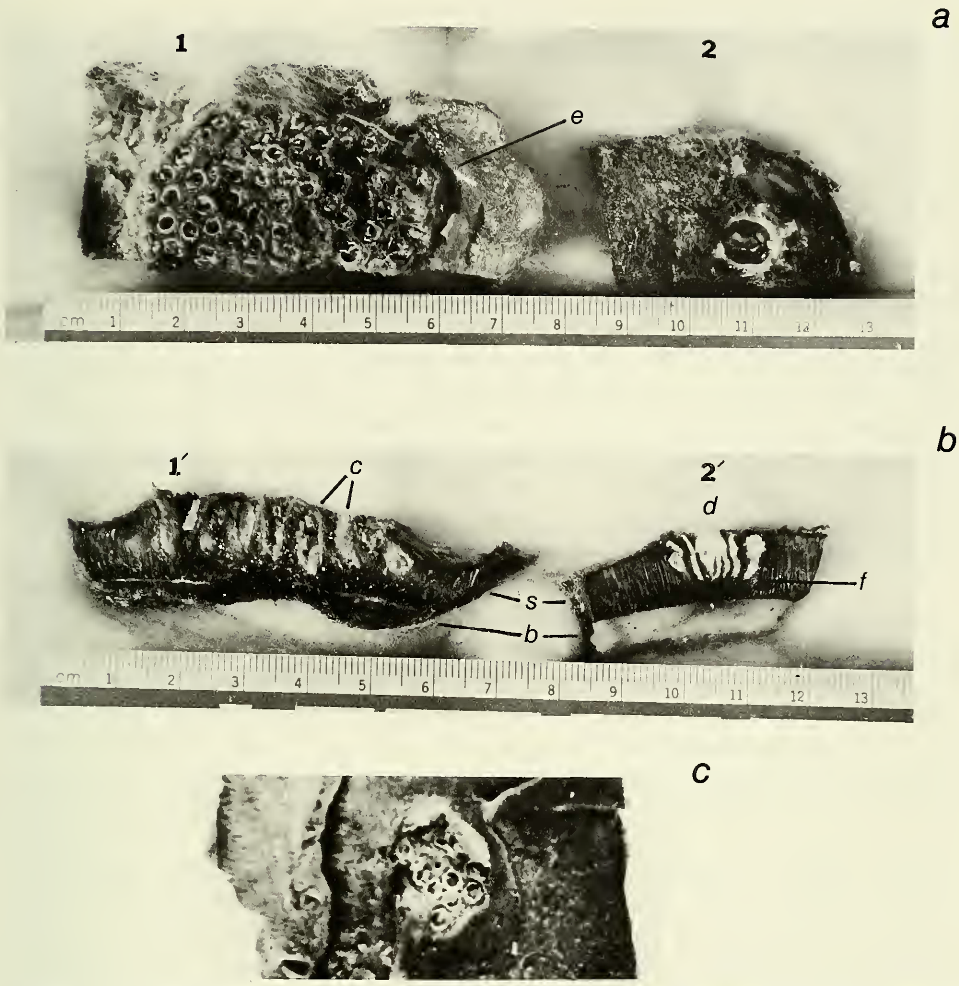

Fig. 9. a1: Dorsal view of a cluster of "seed" barnacles (*Cryptolepas rhachianecti*). Note surrounding ring of irritated, cornified dermis at e. a2: 17 mm in diameter barnacle. b1: Cross-sectional view of barnacle cluster a1 (dorsal is up). c: Note the cylindrical form and depth of penetration of the neo-parapets (3–4 mm in diameter) as opposed to the fluted, elliptically-shaped, more mature barnacle at 2d; s is skin; b is blubber; f is the basis of the barnacle. c: The cluster c includes eighteen barnacles in an area about the size of a penny (15 mm in diameter).

of the genus *Sacculina* and other rhizocephalids. In *Sacculina* the cypris attaches by its antennae to a crab seta and inserts itself as a small mass of undifferentiated cells (see Green 1961; Barnes 1963) by means of a short dart-like tube that pierces the integument of the host. Figure 4a shows a series of attenuated pits of very small diameter in the skin of a young gray whale (Table 1 LACM-54548). These pits possibly mark the points of penetration and insertion of the cypris larvae of *C. rhachianecti*. In the immediate area of these pits is a small (3 mm in diameter) barnacle that has not yet fully developed its protective, calcareous parapet (Fig. 4b). Insertion of *C. rhachianecti* into the epidermis of the gray whale, therefore, might be similar to that of *Sacculina* into crabs.

The rate of growth of *C. rhachianecti* appears to be quite rapid from attachment to the fully mature cirriped (40–50 mm in diameter and about 20 mm thick). In February 1977 the senior author observed numerous gray whale calves, estimated to be six to eight weeks old, with a full array of large barnacles covering their rostra. They were leaving Laguna Guerrero Negro accompanied by their mothers and presumably starting their Northward migration to the Artic. Similar observations were made in Bahia Magdalena in mid-February of 1978.

Six of the whales in Table 1 were immature, their estimated ages varying from less than a year to two years. All six possessed complements of large, mature barnacles, as well as smaller ones in various stages of development. All of these animals bore white, circular barnacle scars characteristic of gray whales. It is believed, therefore, that the calf acquires its initial population of barnacles, via the free-swimming cypris larva stage, very soon after birth by direct contact with the mother and her concomitant population of barnacles and/or from planktonic *C. rhachianecti* cypris larvae in the surrounding waters in areas of high gray whale concentration such as Laguna Ojo de Liebre (Scammon's Lagoon) and Laguna San Ignatio. The rate of growth of the barnacle from insertion to fully maturity would then appear to be from two to three months.

The developing barnacle produces a cyst-like area of irritation on the surrounding skin of the whale. *Cyamus ceti* and *C. scammoni* appear to feed on the disturbed epidermis around and ultimately beneath the mature barnacle (Fig. 7b). Irritation or trauma of the host's tissue and a propensity for aggregation may attract the cyamids to feed in areas with barnacles. *C. scammoni* and/or *C. ceti* are always found clustered around barnacles on the gray whale. The whale's skin changes color from gray-black to white as feeding takes place. This also seems to be the case as surface wounds heal. Feeding progresses around and under the barnacle until it is completely undercut (Fig. 7). *C. ceti* appears to be the initial cyamid to begin feeding on the skin around juvenile barnacles. *C. ceti* has been observed feeding almost exclusively around barnacles up to 10 mm in diameter (Fig. 5c). *C. ceti* is rarely encountered in close proximity to barnacles larger than 20–30 mm in diameter. It is presumed that the larger, perhaps more aggressive, *C. scammoni* has supplanted it as the primary feeder. By the time the barnacle reaches 20–30 mm in diameter, the feeding cyamids have removed that portion of skin which initially overlapped the dorsal portion of the barnacle as far as the operculum. From this point on, the principal feeding area is around the immediate periphery of the barnacle (Fig. 6a). Both sexes and all stages of development of *C. scammoni* are found in this area (Fig. 1a).

Figures 6b and c show the sites of two recently undercut and detached barnacles. Figure 6b shows remnant supporting skin (corium papillae) between the flutes of the barnacle's parapet; and in Fig. 6c can be seen the impression left by the ventral surface of the parapet. Following extensive undercutting by feeding cyamids, final removal of the barnacle may be effected by: water currents along the skin of the whale; by the whale scraping along rocks or sand; and/or, by breaching.

On the stranded whales studied by the authors (Table 1), it appeared that at the site where a barnacle had recently been sloughed-off, the density of the cyamids decreased drastically. It is not known whether the cyamids move to the site of a new cirriped or simply end their life cycle. After the barnacle is detached, the black attachment site turns white in color and merges imperceptibly into the rest

of the feeding scar (Figs. 6d, e, and f). The final appearance of the feeding and attachment sites appears most commonly as a circular white scar (Fig. 6f) and less frequently as an oval scar (Fig. 6d).

The authors did not observe the direct transfer of cyamids from parent to a newborn gray whale calf. Indirect evidence indicates that contact, during and soon after birth, is the method by which the calf acquires its initial population of cyamids. Gray whale calves, estimated to be 3–4 weeks old, were observed by the senior author in Laguna Guerrero Negro and Bahia Magdalena with clusters of cyamids around their external nares and on the dorsum just posterior to the nares.

While diving around the caracass of an 8.4 m long female gray whale that had nearly been decapitated by a ship propeller (Table 1, WFS-1035), the same observer experienced an immediate transfer of hundreds of lice from the whale upon contact with areas of cyamid aggregations. Except for three large, mature *C. scammoni,* all the rest in this transfer were immature *C. scammoni* with possibly a few immature *C. ceti.* This probable transference of predominantly immature cyamids to the calf, coupled with the very rapid growth rate of the barnacle, should provide a ready food supply for them in a matter of days or, at the most, within two or three weeks.

This interaction between the cyamids and the barnacle represents an unique feeding arrangement. In feeding directly on the skin of the whale, *C. scammoni* and *C. ceti* could be referred to as parasites. On the other hand, cyamids feeding on damaged tissue in wounds and on irritated skin around erupting barnacles may aid in the healing process, as well as removing the barnacle, a source of irritation to the whale. This could be considered a mutualistic relationship. The barnacle is essentially a passive associate or "phoresitic commensual" (see Noble and Noble 1976).

After causing the removal of the barnacle, cyamids no longer continue to feed at the site. Consequently, the wound is allowed to heal with no visible evidence of the preexistence of the barnacle other than the change of color of the site from gray-black to white. The relationship seems to prove mutually beneficial to the cyamids and the whale, but not to the barnacle. Cyamids, at least *C. scammoni* and *C. ceti,* may provide a mechanism whereby the cirriped population is numerically controlled.

Limited data at hand indicate that *Cyamus kessleri* is an ectoparasite of the gray whale. Although the Cyamidae have been described as the only truly parasitic amphipods, *C. scammoni* and *C. ceti* may well be the exceptions.

Acknowledgments

We thank Mary K. Wickston (Texas A&M University) for comments on parasitic barnacles and assistance in reviewing the manuscript. We are grateful to Donald Patten (Natural History Museum of Los Angeles County), J. L. Mohr (University of Southern California) and John Ljubenkov, Robert Osborn, and Stephen Leatherwood for their valuable criticisms, and Mary Samaras for her assistance in collecting and organizing specimens. We thank Terri Hoban, Stephen Leatherwood, and Jean Mason, Senior Staff Technologist U.S.C., for the use of their photographs and X-rays.

Literature Cited

Barnes, R. D. 1963. Invertebrate zoology. W. B. Saunders Co., Philadelphia, 420 pp.

Brandt, A. 1872. Brecht uber die cyamiden des zoologischen museum der Kaiserlichen Akademie der Wissenchaten zu St. Petersburg, Bull. Acad. Imp. Sci. St. Petersburg, 18:113–133.

Briggs, K. T., and G. V. Morejohn. 1972. Barnacle orientation and waterflow characteristics in California gray whales. J. Zool., 167(3):287–292.

Dall, W. H. 1872. Description of three new species of Crustacea parasitic on the Cetacea of the N.W. coast of America. Proc. California Acad. Sci., 4:281–283.

Green, J. 1961. A biology of Crustacea. London: H. F. & G. Witherby Ltd. Revised, 180 pp.

Hurley, D. E., and J. L. Mohr. 1957. On whale-lice (Amphipoda: Cyamidae) from the California gray whale, Eschrichtius glaucus. J. Parasitology, 43(3):352–357.

Leung, Y. M. 1967. An illustrated key to the species of whale-lice (Amphipoda: Cyamidae), ectoparasites of Cetacea, with a guide to the literature, Crustaceana, 12:279–291.

———. 1976. Life cycle of Cyamus scammoni (Amphipoda: Cyamidae), ectoparasites of the gray whale, with a remark on the associated species. Sci. Rep. Whales Res. Inst., 28:153–160.

Linnaeus, C. 1758. Systema Naturea, 10th ed., 1:1–824, 1–111 (L. Salvii, Holimae).

Margolis, L. 1955. Notes on the morphology, taxonomy and synonymy of several species of whale-lice (Amphipoda: Cyamidae). J. Fish. Res. Bd., Canada, 12:121–133.

Noble, E. R., and G. A. Noble. 1976. The biology of animal parasites (4th ed.) Lea and Febiger, Philadelphia. 566 pp.

Rice, D. W., and A. A. Wolman. 1971. The life history and ecology of the gray whale (*Eschrichtius robustus*). Amer. Soc. Mamm. Special Publications, 3:140 pp.

Zimushko, V. V. 1970. Age determination of the gray whale (*Eschrichtius gibbosus,* Erx. 1777). Proceedings of the Pacific Scientific Research Inst. of Marine Fisheries and Oceanography (TINRO), 71:295–300, Magadan.

Accepted for publication 21 June 1983.